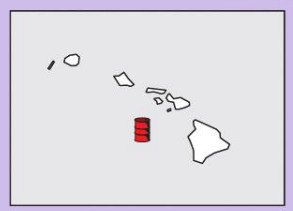
Geological CO_2 Sequestration: The key to economic survival in a carbon constrained world

Ronald Surdam
State Geologist
Director WSGS

Zunsheng Jiao
Senior Geologist
WSGS

Net Domestic Energy
Export vs. Import



= 4 quadrillion Btu's from fossil fuel

STATE OF WYOMING
1933
GEOLOGICAL SURVEY

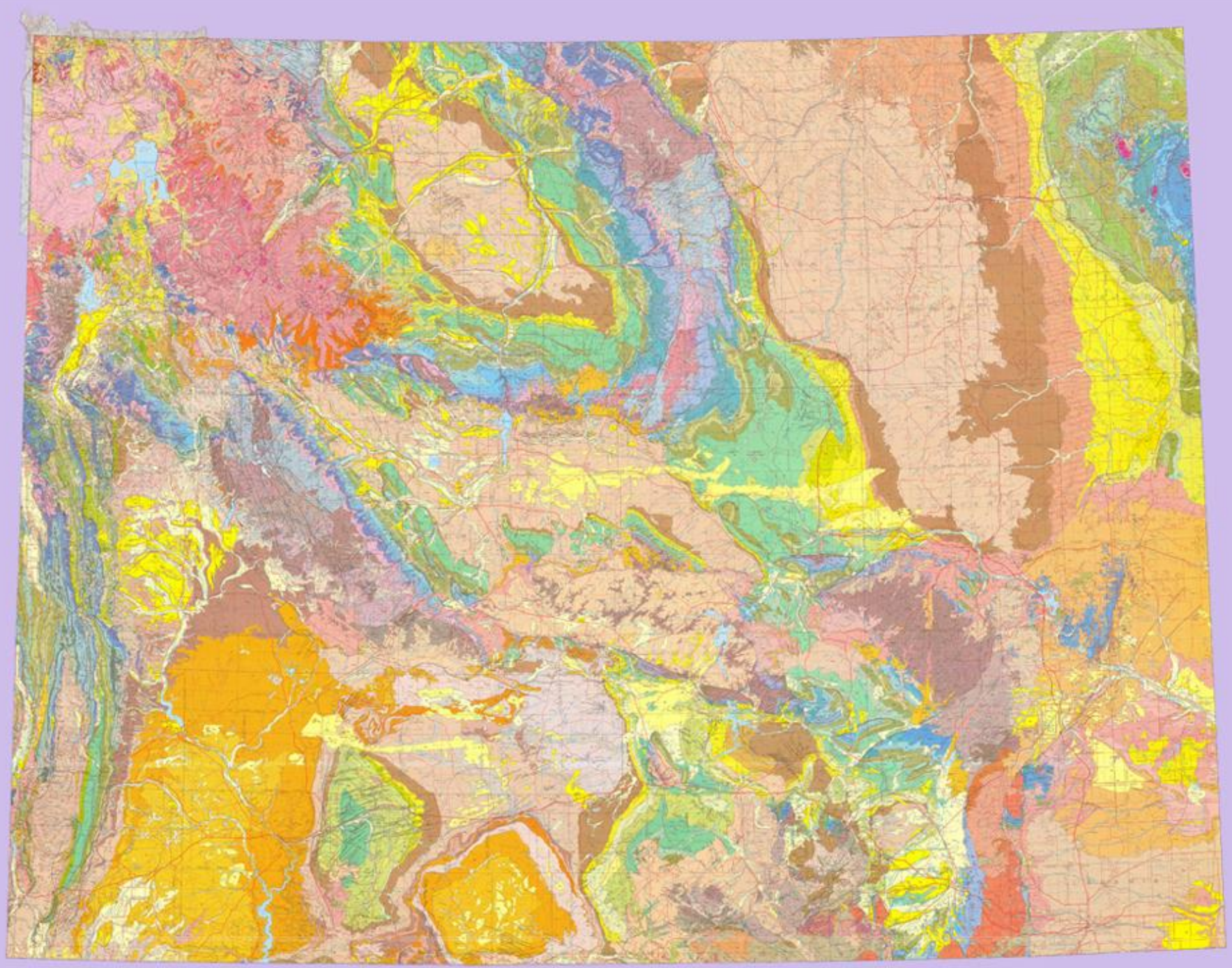
U.S. Energy Imports
2006

Rank	Country or State of Origin	Crude Oil Production Million Bbl/year	Crude Oil Quadrillion Btu	Natural Gas Production Trillion Cubic ft/year	Natural Gas Quadrillion Btu	Coal Production million tons/year	Coal Quadrillion Btu	Total Quadrillion Btu
1	Wyoming	52.93	0.28	1.75	1.77	446.74	7.96	10.01
2	Canada	648.97	3.41	3.59	3.63	1.49	0.04	7.08
3	West Virginia	1.83	0.01	0.22	0.22	152.37	3.91	4.14
4	Mexico	575.61	3.02	0.01	0.01	0.00	0.00	3.04
5	Saudi Arabia	519.40	2.73	0.00	0.00	0.00	0.00	2.73
6	Venezuela	416.83	2.19	0.00	0.00	3.07	0.08	2.27
7	Nigeria	378.51	1.99	0.06	0.06	0.00	0.00	2.05
8	Alaska	270.47	1.42	0.42	0.43	0.00	0.00	1.85
9	Iraq	201.85	1.06	0.00	0.00	0.00	0.00	1.06
10	Angola	187.25	0.98	0.00	0.00	0.00	0.00	0.98
	Total	3,253.61	17.08	6.05	6.12	603.67	11.99	35.19

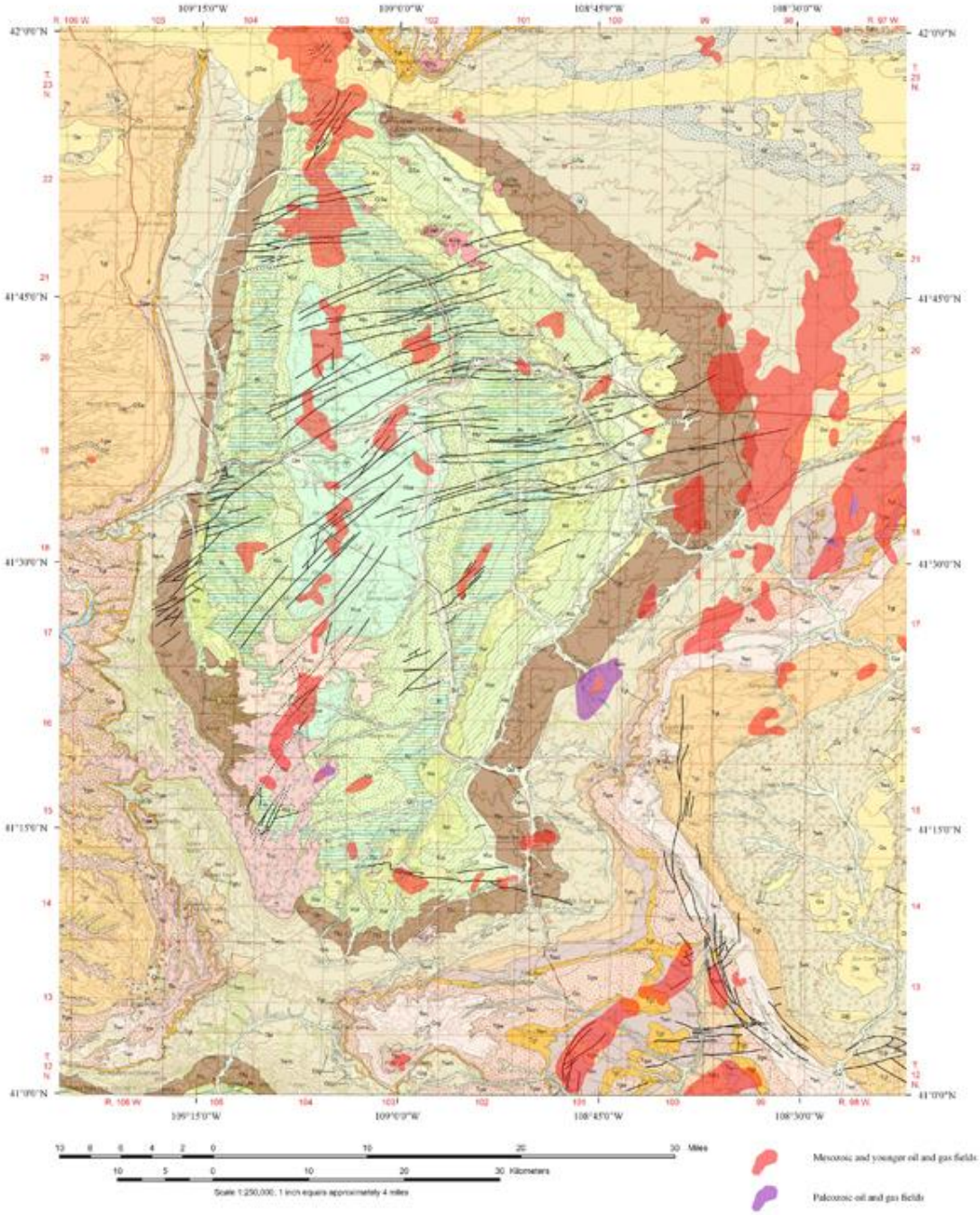
Note: Total may not equal sum of components because of independent rounding.
Coal imports include coal to Puerto Rico and the Virgin Islands.

Source: Bureau of the Census, U.S. Department of Commerce, *Monthly Report IM 145.*
EIA, U.S. Natural Gas Imports by Country
EIA, U.S. Crude oil Net Imports by Country
EIA, Gross Heat Content of Coal Production, Most Recent Annual Estimates, 1980-2006

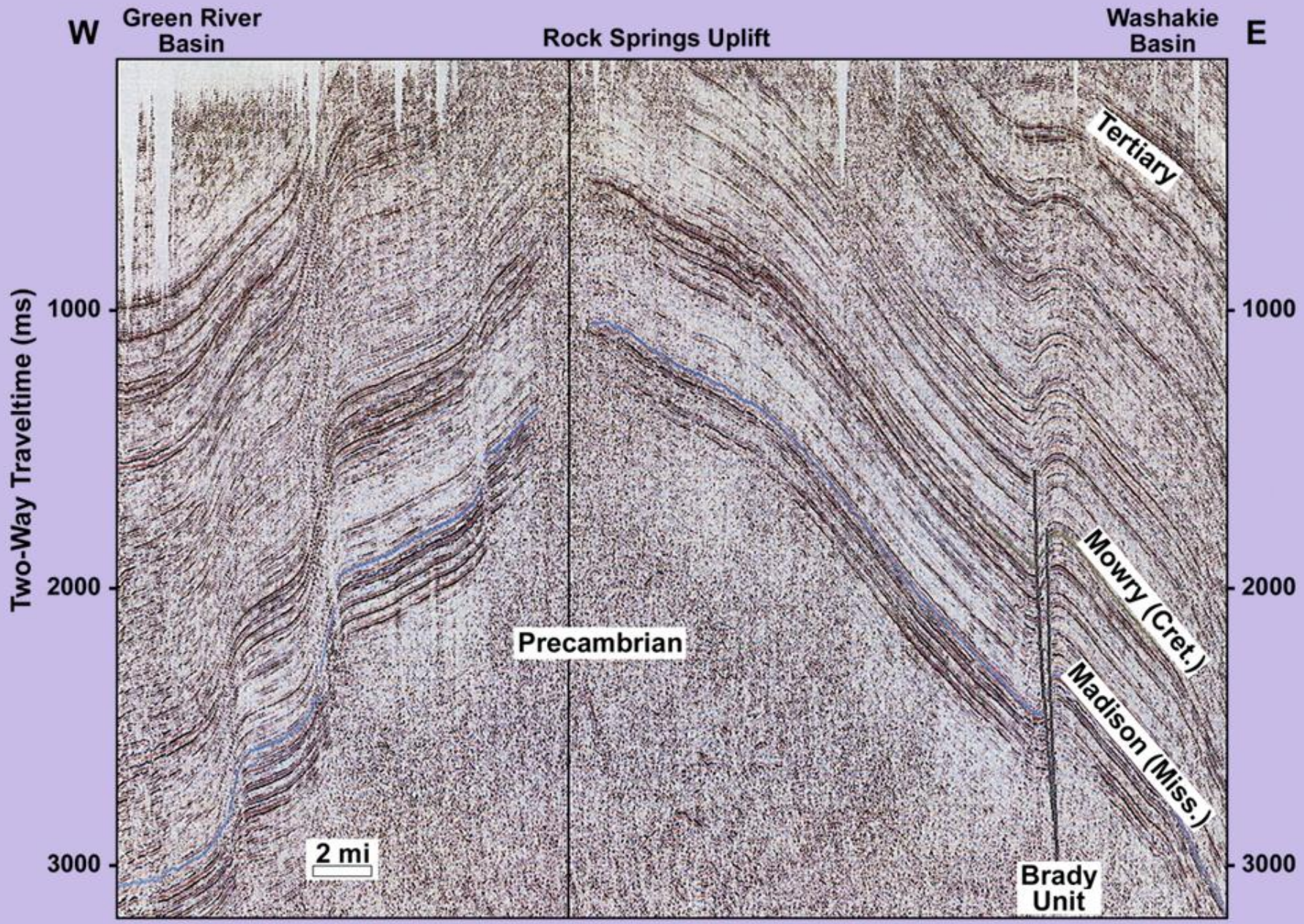
STATE OF WYOMING GEOLOGICAL SURVEY 1933



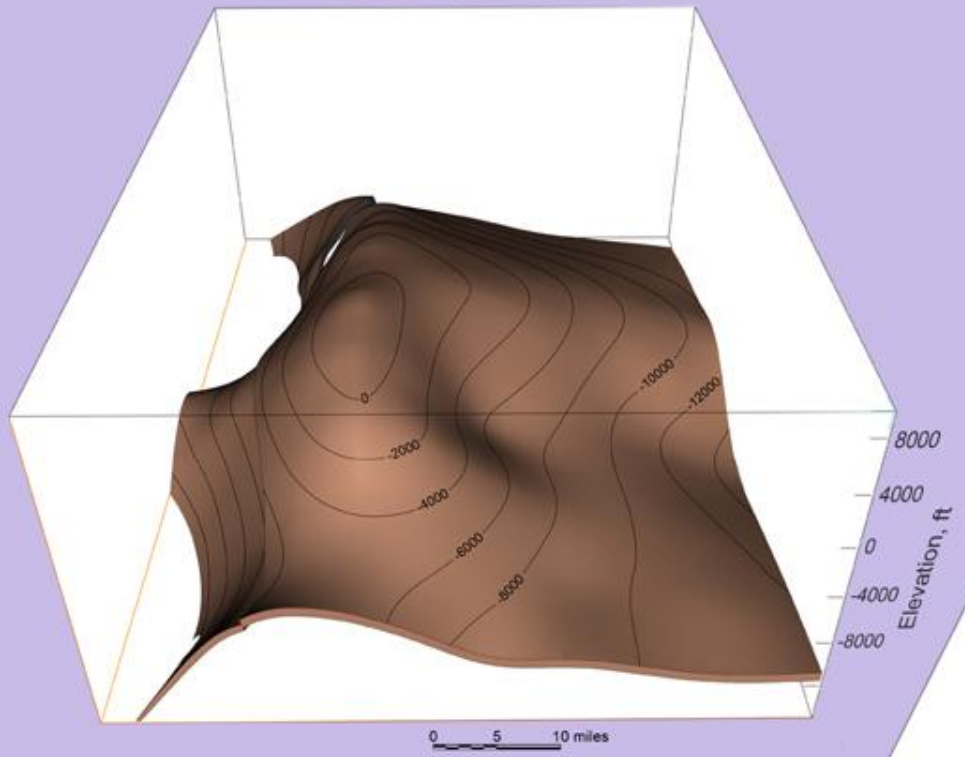
GEOLOGIC MAP AND OIL AND GAS FIELDS OF THE ROCK SPRINGS UPLIFT AREA, SWEETWATER COUNTY, SOUTHWESTERN WYOMING



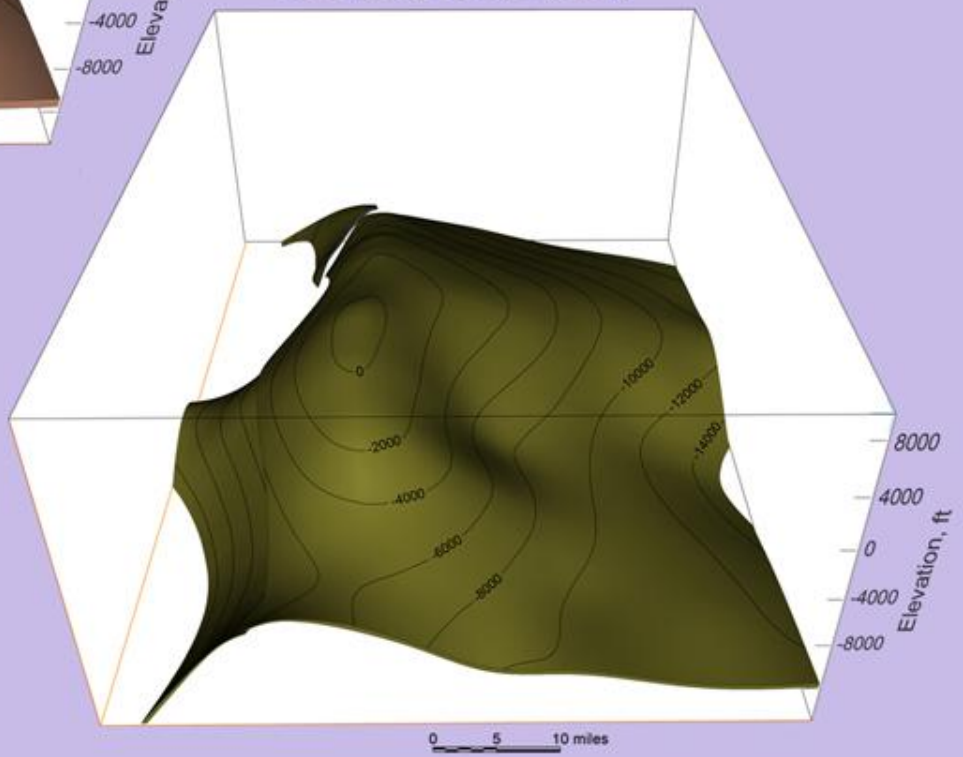
STATE OF WYOMING
1933
GEOLOGICAL SURVEY


W
Green River Basin
Rock Springs Uplift
Washakie Basin
E
Two-Way Traveltime (ms)
1000
2000
3000
Tertiary
Mowry (Cret.)
Madison (Miss.)
Precambrian
2 mi
Brady Unit

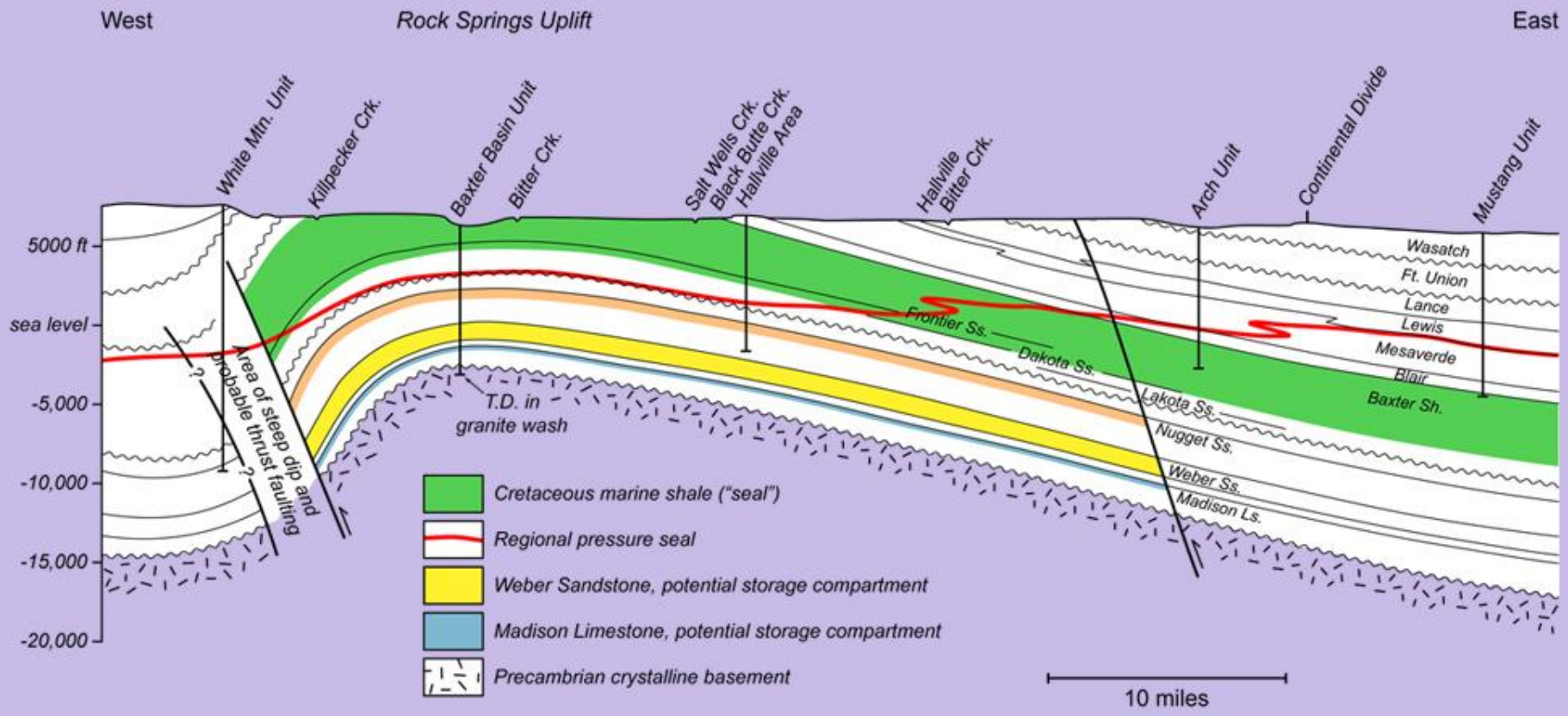
Weber Sandstone
Rock Springs Uplift, Wyoming



Madison Limestone
Rock Springs Uplift, Wyoming

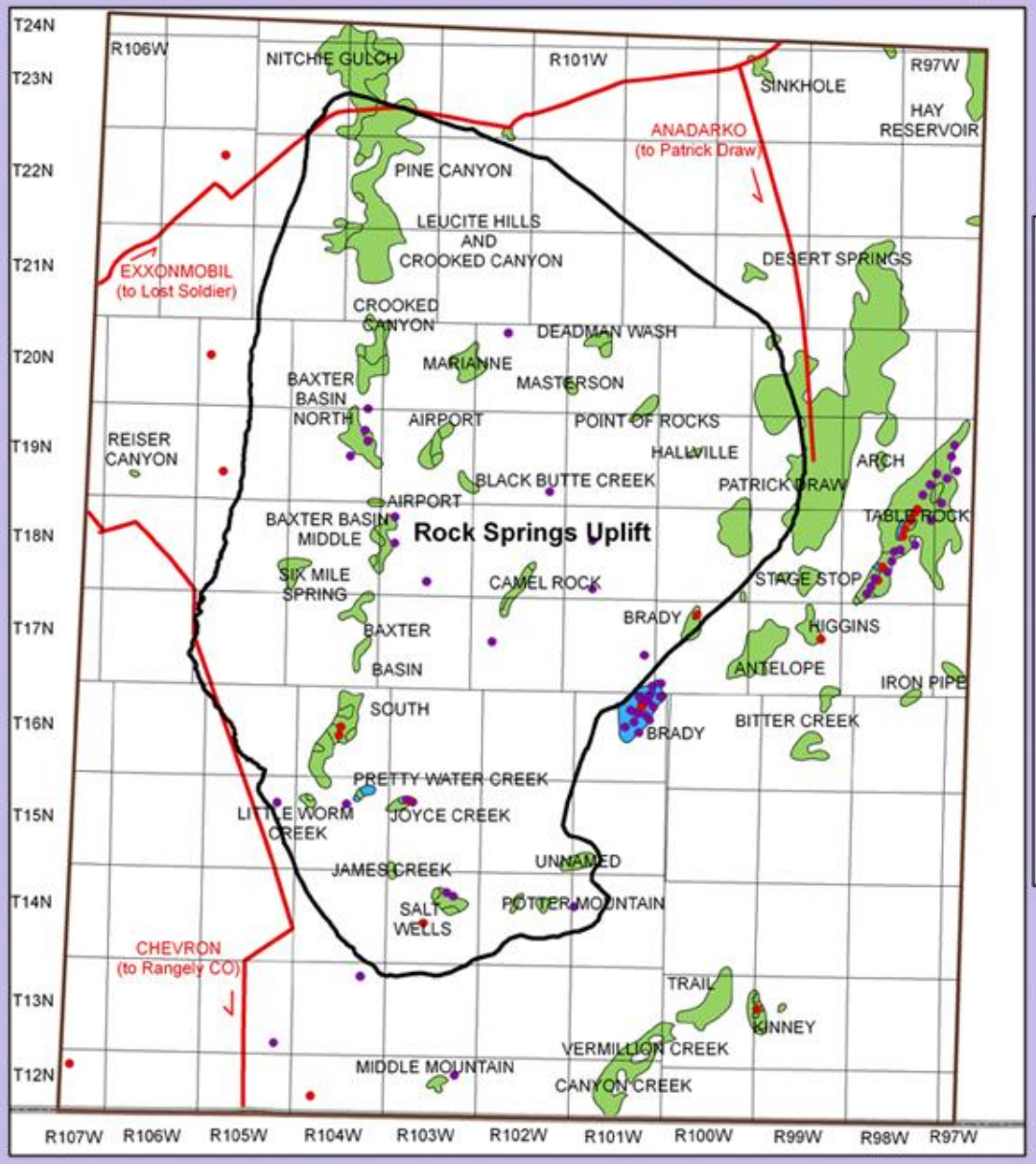


STATE OF WYOMING
GEOLOGICAL SURVEY
1933



STATE OF WYOMING
1933
GEOLOGICAL SURVEY

Oil and Gas Fields in the Rock Springs Uplift Area



Legend

Oil and Gas Field Ages

- Mesozoic
- Paleozoic

Oil and Gas Tests

- Weber Penetrations (55)
- Madison Penetrations (20)

Other Map Features

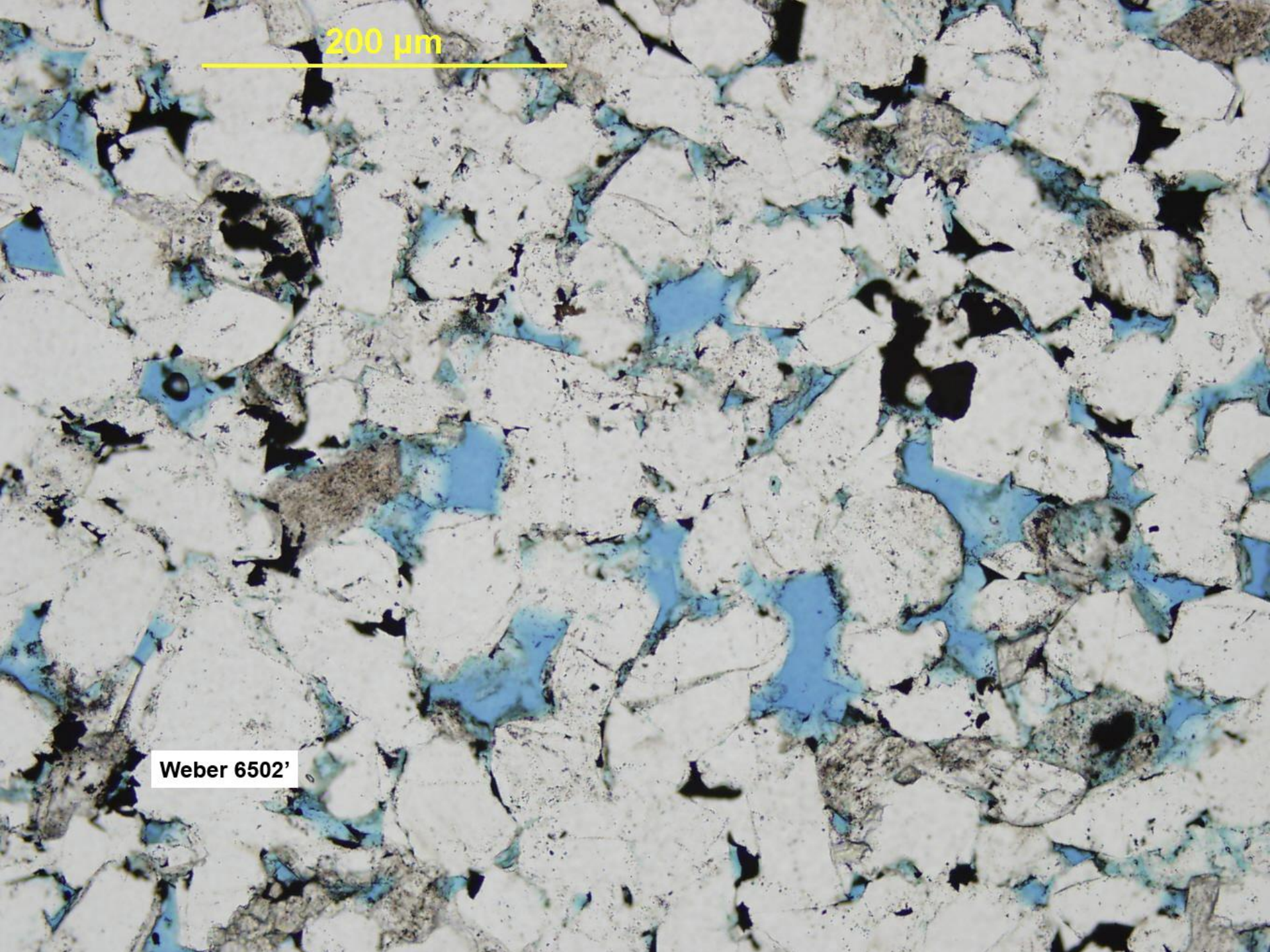
- CO_2 Pipelines
- Uplift Boundary
- Project Border
- Township-Range Lines
- State Border

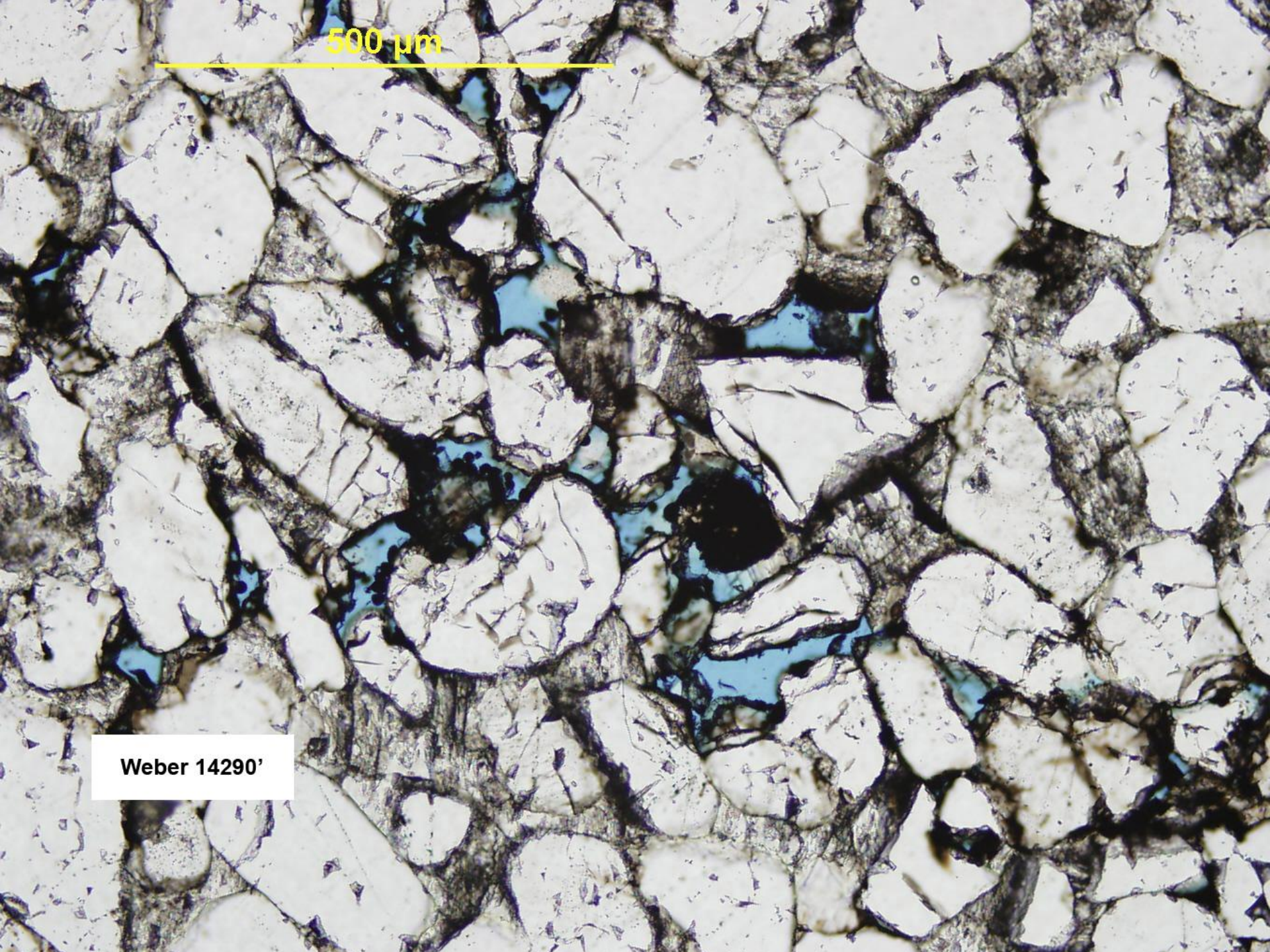
N

Scale

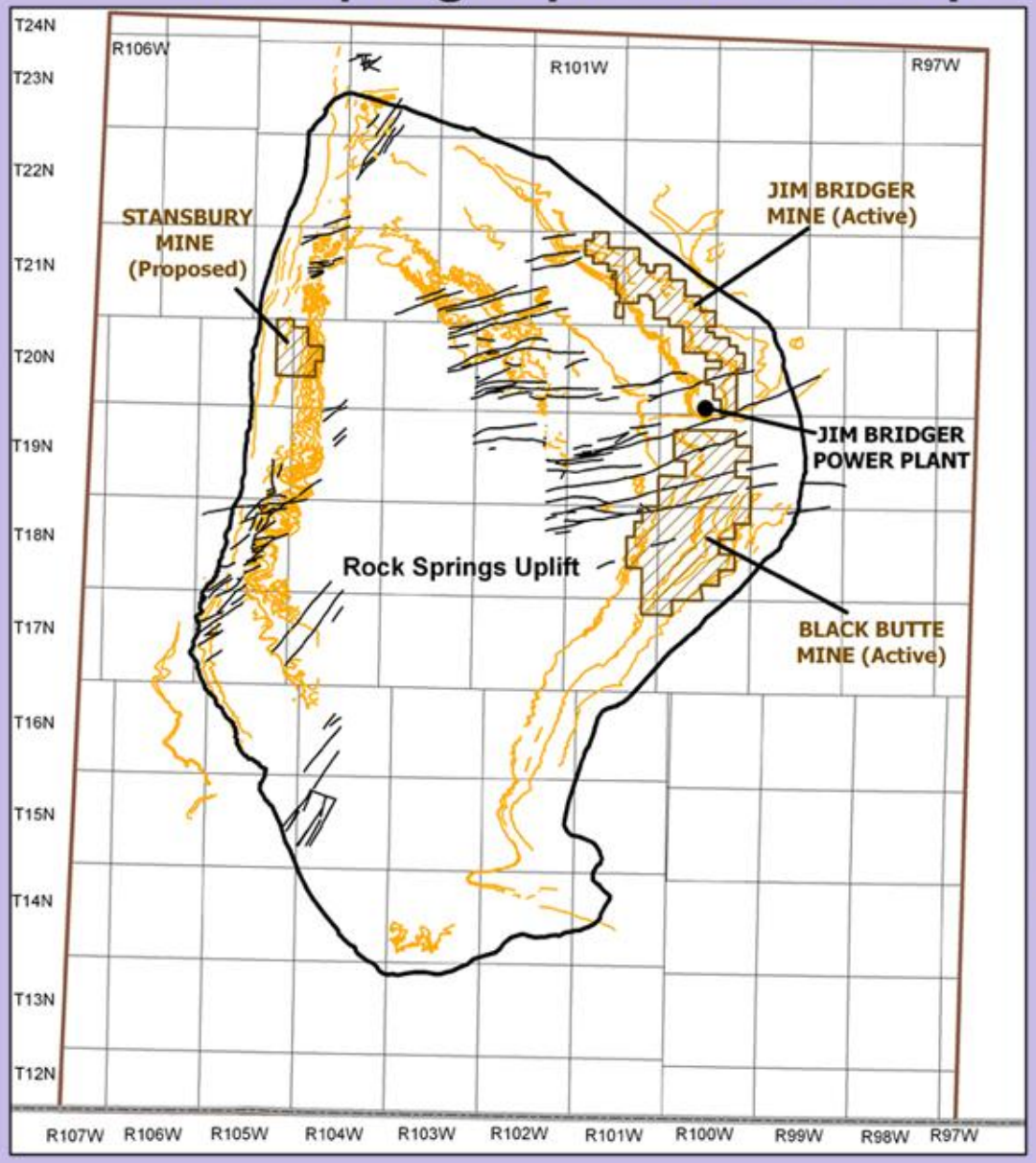
0 2 4 8 12 16 Miles

STATE OF WYOMING GEOLOGICAL SURVEY 1933


200 µm
Weber 6502’


500 µm
Weber 14290'

Rock Springs Uplift Coal Outcrops and Active Mines



Legend

- Coal Mines
- Coal Outcrops
- Faults
- Uplift Boundary
- Project Border
- Township-Range Lines
- State Border

Jim Bridger Power Plant

2110 megawatts power production
Emits approximatley 18.5 million tons CO_2 per year

Jim Bridger Mine

Surface and Underground Mine

Black Butte Mine

Surface Mine

Black Butte Mine

Formerly called "Little Patriot"

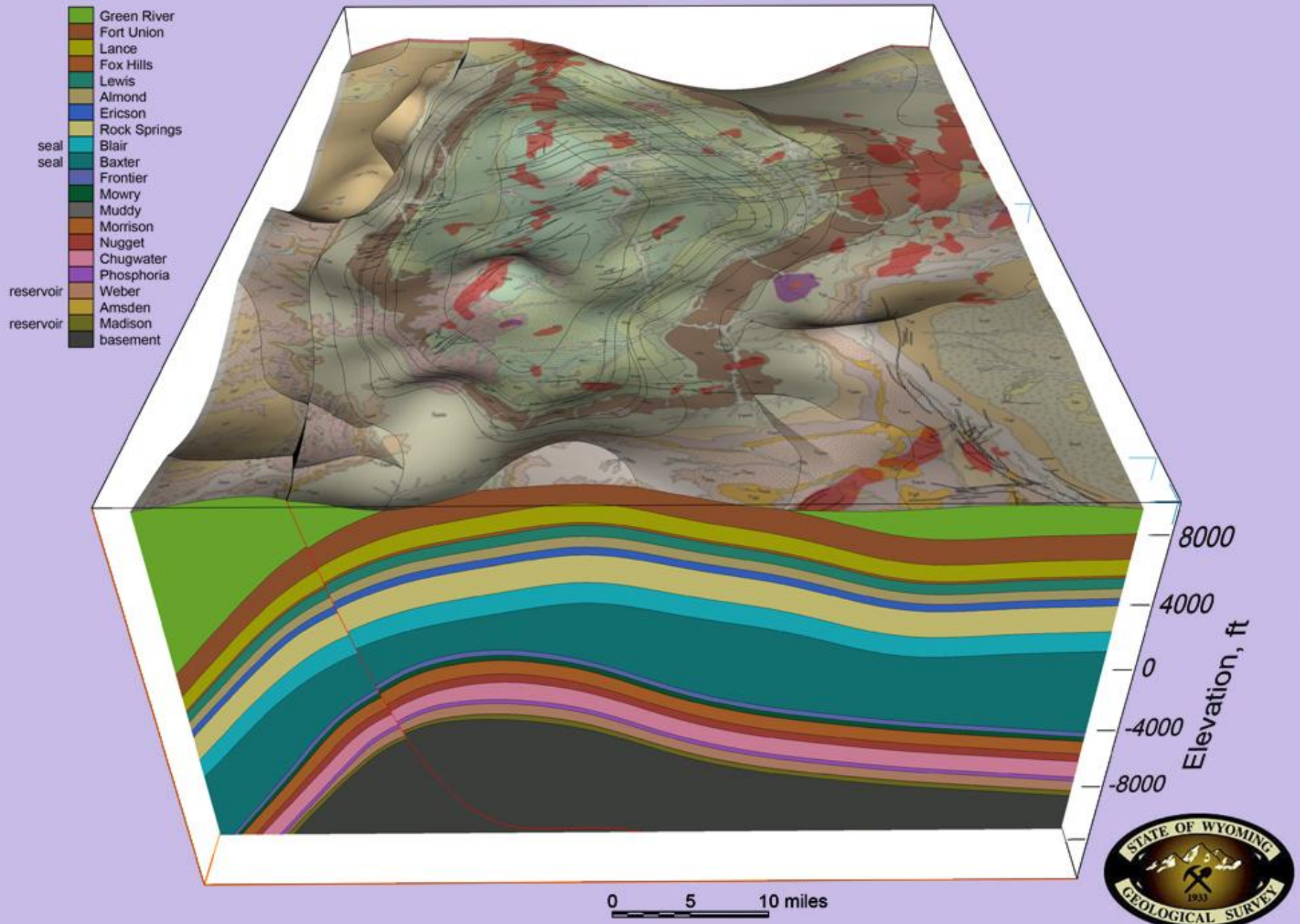
N

Scale

Miles
0 2 4 8 12 16

STATE OF WYOMING GEOLOGICAL SURVEY 1933

Rock Springs Uplift, Wyoming

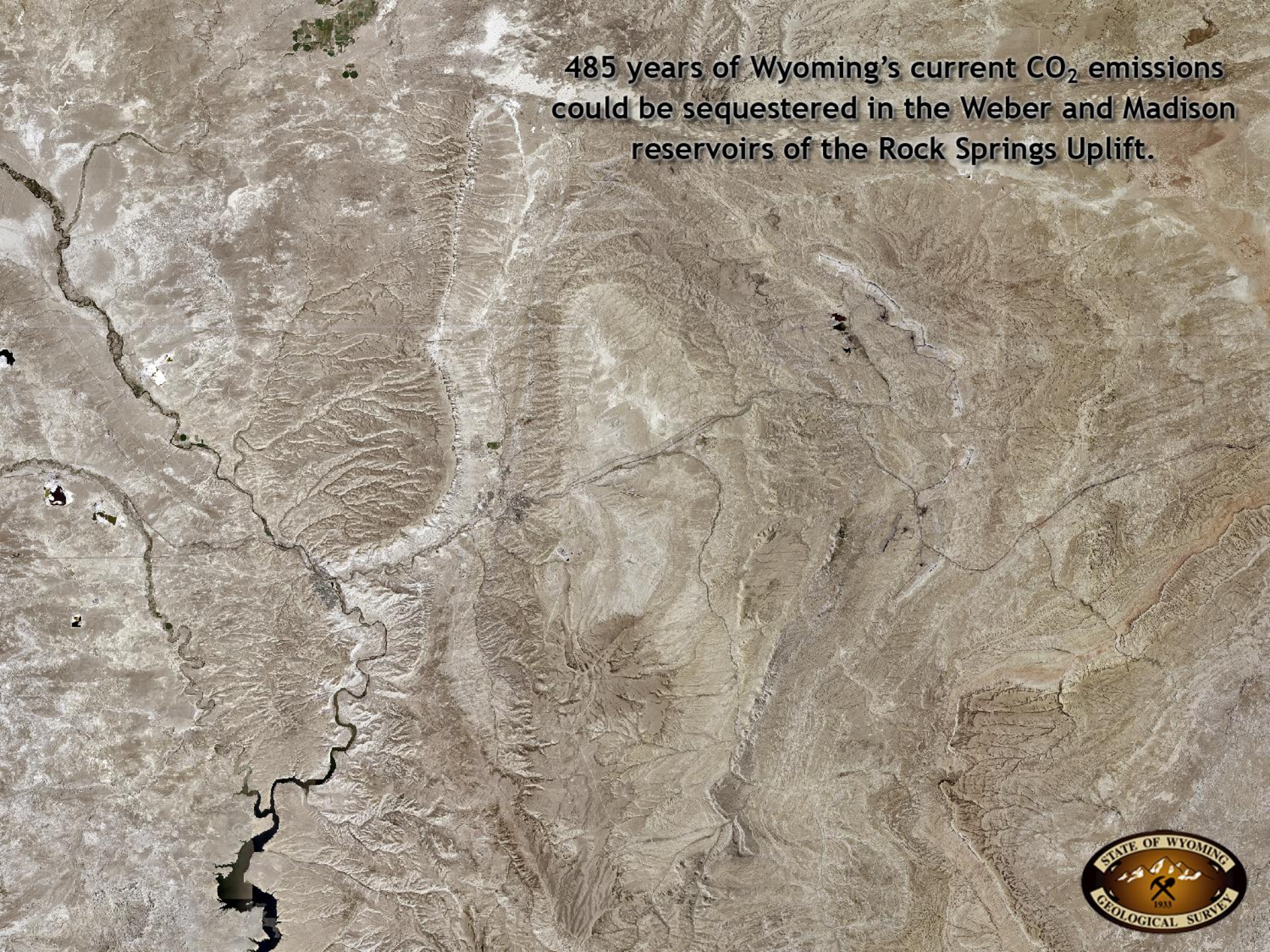


Sequestration capacity of the Weber Sandstone and Madison Limestone, Rock Springs Uplift, Wyoming.

Input parameters	Weber		Madison	
	Value	*Unit*	*Value*	*Unit*
Formation depth	1,893	meters	2,286	meters
Formation thickness	225	meters	98	meters
Effective porosity	10.0	%	10.0	%
Temperature	60	°C	71	°C
Dissolved NaCl	0.5	molal	0.5	molal
Calculated parameters				
Formation pressure (observed)	$1.85 \cdot 10^{7}$	Pa	$2.24 \cdot 10^{7}$	Pa
CO_2 density (in reservoir condition)	$6.88 \cdot 10^{2}$	kg/m^3	$6.90 \cdot 10^{2}$	kg/m^3
CO_2 fugacity coefficient	$4.82 \cdot 10^{-1}$		$4.81 \cdot 10^{-1}$	
CO_2 Henry's constant	$3.98 \cdot 10^{8}$	Pa	$4.73 \cdot 10^{8}$	Pa
CO_2 aqueous mass fraction	$5.48 \cdot 10^{-2}$	kg/m^3	$5.57 \cdot 10^{-2}$	kg/m^3
Aqueous density	$1.01 \cdot 10^{3}$	kg/m^3	$1.01 \cdot 10^{3}$	kg/m^3
Water content (steady state)	7.00	%	7.00	%
Fixed parameter				
Mass of injected CO_2	$5.00 \cdot 10^{7}$	tonnes	$5.00 \cdot 10^{7}$	tonnes
Results				
Formation supercritical CO_2 capacity	$2.06 \cdot 10^{1}$	kg/m^3	$2.07 \cdot 10^{1}$	kg/m^3
Formation dissolved CO_2 capacity	3.88	kg/m^3	3.93	kg/m^3
CO_2 plume area	9.06	km^2	$2.07 \cdot 10^{1}$	km^2
CO_2 plume volume	2.04	km^3	2.03	km^3
Supercritical CO_2	$4.21 \cdot 10^{7}$	tonnes	$4.20 \cdot 10^{7}$	tonnes
Dissolved CO_2	$7.91 \cdot 10^{6}$	tonnes	$7.98 \cdot 10^{6}$	tonnes
CO_2 (mcf)	$6.58 \cdot 10^{5}$	mcf	$7.79 \cdot 10^{5}$	mcf
CO_2 (square miles)	3.54	mi^2	8.09	mi^2
Plume radius	1.06	mi	1.60	mi
Rock Springs Uplift (area bounded by Tfu outcrop)	$1.30 \cdot 10^{3}$	mi^2	$1.30 \cdot 10^{3}$	mi^2
Total CO_2 injection capacity	$1.84 \cdot 10^{10}$	tonnes	$8.04 \cdot 10^{9}$	tonnes

Total CO_2 that can be injected into the Weber and the Madison	$2.64 \cdot 10^{10}$ tonnes
Current Wyoming CO_2 emissions (coal-fired and gas processing plant)	$5.44 \cdot 10^{7}$ metric tonnes $6.00 \cdot 10^{7}$ short tons
Number of years Wyoming CO_2 emissions could be sequestered in the Weber and Madison reservoirs, Rock Springs Uplift, Wyoming	485 years

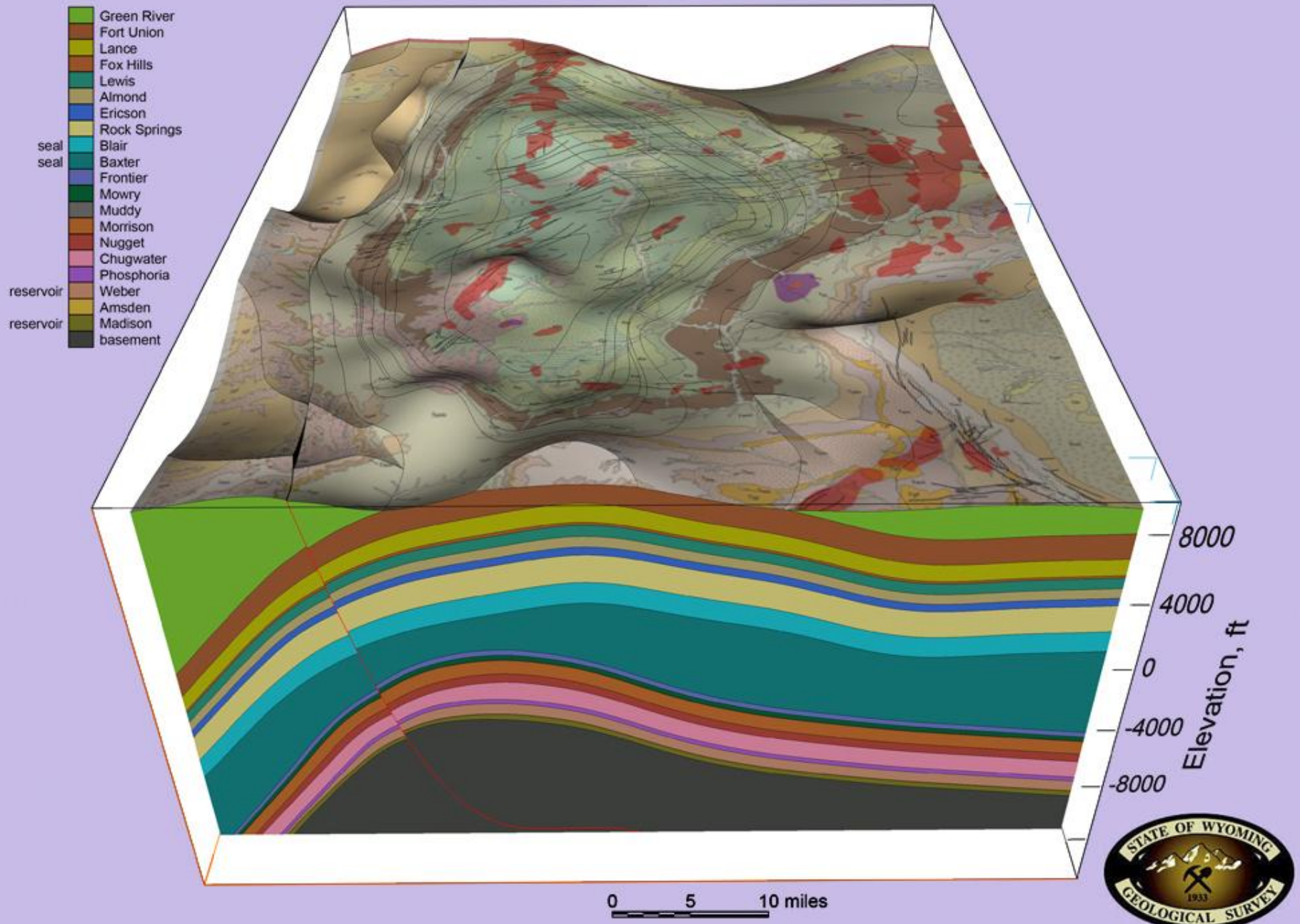
STATE OF WYOMING GEOLOGICAL SURVEY 1933

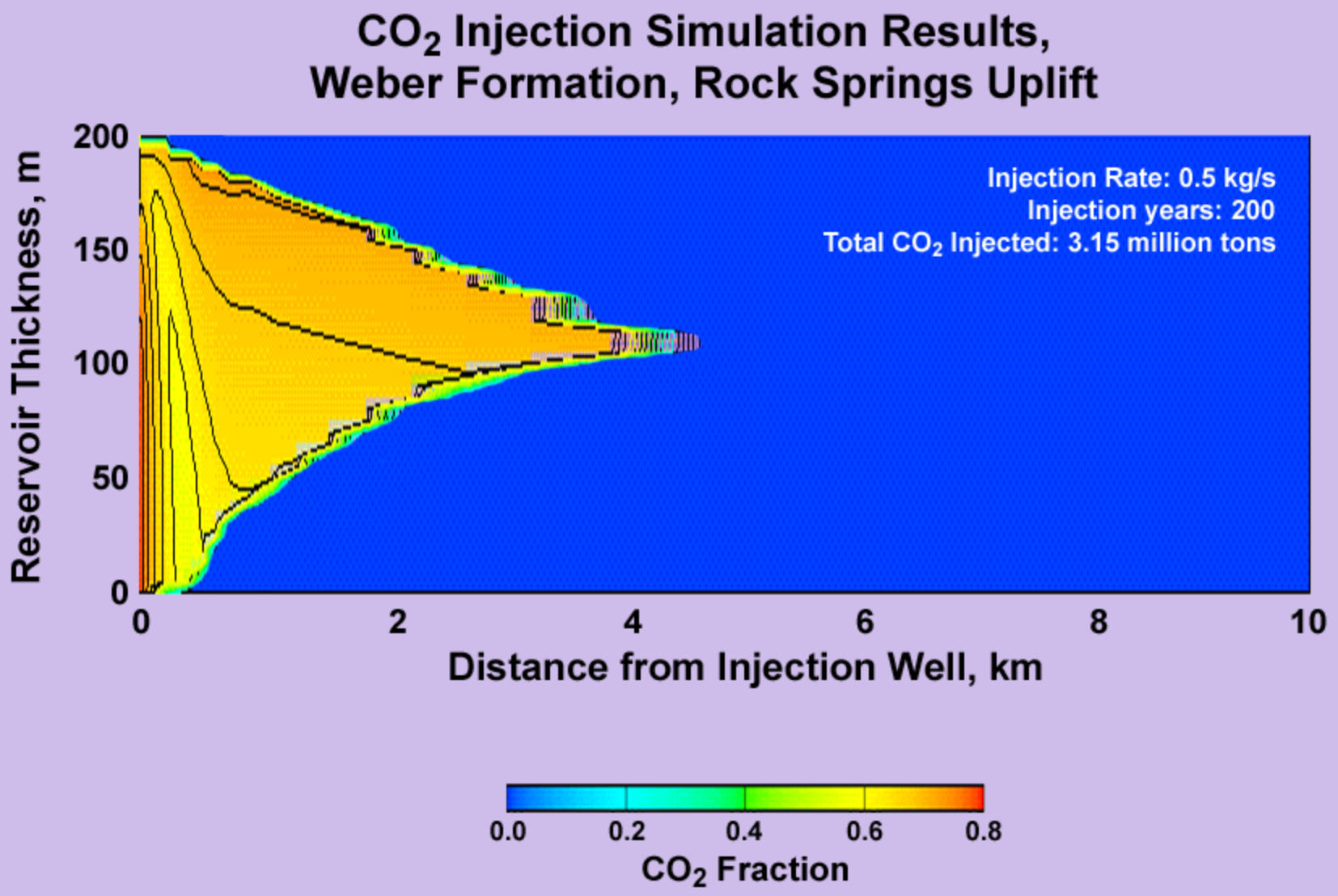

485 years of Wyoming's current CO_2 emissions could be sequestered in the Weber and Madison reservoirs of the Rock Springs Uplift.
STATE OF WYOMING
1933
GEOLOGICAL SURVEY

Future Work

- **Refine the geological framework required for 3-D rock fluid modeling of the Rock Springs Uplift (RSU).**
- **Construct a 3-D numerical model of CO_2 injection into the RSU.**
- **Build a Performance Assessment (PA) model that includes uncertainty and that can be utilized to construct a Probabilistic Risk Analysis (PRA) for CO_2 sequestration at the RSU.**

Rock Springs Uplift, Wyoming




CO_2 Injection Simulation Results,
Weber Formation, Rock Springs Uplift
Reservoir Thickness, m
200
150
100
50
0
0
2
4
6
8
10
Distance from Injection Well, km
Injection Rate: 0.5 kg/s
Injection years: 200
Total CO_2 Injected: 3.15 million tons
0.0
0.2
0.4
0.6
0.8
CO_2 Fraction

A SYSTEM MODEL FOR GEOLOGIC SEQUESTRATION OF CARBON DIOXIDE

CO2_PENS,

Los Alamos/Goldsim

Rock Springs Uplift: an outstanding geological CO_2 sequestration site in southwestern Wyoming

- Thick saline aquifer sequence overlain by thick sealing lithologies.
- Doubly-plunging anticline characterized by more than 10,000 ft of closed structural relief.
- Huge area (50 x 35 mile).
- Required reservoir conditions; including, but not limited to fluid chemistry, porosity (pore space), fluid-flow characteristics, temperature and pressure (i.e., regional burial history).
- Technology available to monitor the injected CO_2 plume.